Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences
Pacific Region

Canadian Science Advisory Secretariat
Science Advisory Report 2011/017

STOCK ASSESSMENT FOR PACIFIC OCEAN PERCH (*SEBASTES ALUTUS*) IN QUEEN CHARLOTTE SOUND, BRITISH COLUMBIA IN 2010

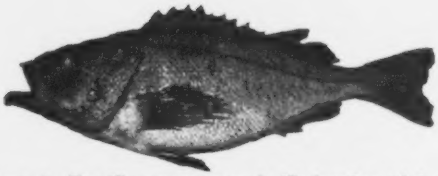

Figure 1. Pacific ocean perch (Sebastes alutus). Credit: Schon Acheson, DFO.

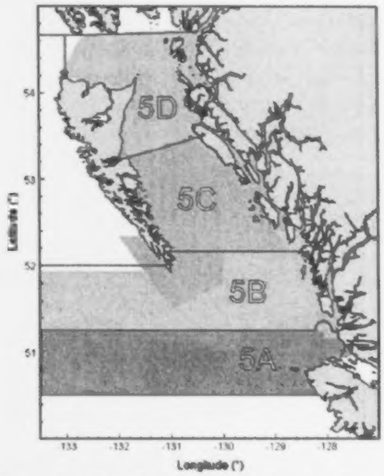

Figure 2. Pacific Marine Fisheries Commission major Areas (outlined in purple). This assessment covers Areas 5A, 5B and 5C Groundfish Management Unit areas for Pacific ocean perch are shaded in four colours.

Context :

Pacific ocean perch (Sebastes alutus) is a commercially important species of rockfish that inhabits the marine canyons along the coast of British Columbia. Of the current annual Total Allowable Catch of rockfish on the west coast of Canada, Pacific ocean perch (POP) is the species that has the largest single-species quota. The status of POP in Queen Charlotte Sound, British Columbia is assessed here under the assumption that it is a single stock harvested entirely in Pacific Marine Fisheries Commission major areas 5A, 5B and 5C (Figure 2). This stock has supported a domestic trawl fishery since the 1960s and was heavily fished by foreign fleets from the mid-1960s to mid-1970s.

The last assessment of POP occurred in 2001 for the population in Goose Island Gully (one of the three gullies in Queen Charlotte Sound), but results were extended to the whole coast. Fisheries and Aquaculture Management of Fisheries and Oceans Canada (DFO) requested advice of the current biomass and status of POP with respect to precautionary reference points, together with decision tables forecasting the impacts of varying harvest levels.

This Science Advisory Report has resulted from a Fisheries and Oceans Canada, Canadian Science Advisory Secretariat Pacific Regional Advisory Meeting of November 24, 2010 on Stock Assessment for Pacific Ocean Perch (Sebastes alutus) in Queen Charlotte Sound, British Columbia. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

SUMMARY

- Pacific ocean perch supports the largest rockfish fishery in British Columbia with an annual coastwide TAC (total allowable catch) of 6,148 t. The trawl fishery receives 99.98% of the coastwide TAC, with the rest allocated to the hook and line fishery.
- Stock status was assessed using an annual two-sex catch-at-age model tuned to three fishery-independent trawl survey series (Goose Island Gully historic, Queen Charlotte Sound synoptic and Queen Charlotte Sound shrimp), annual estimates of commercial catch since 1940, and age composition data from two of the survey series (8 years) and the commercial fishery (29 years). Results presented herein are reported for the two accepted model runs (the first estimated natural mortality and the second kept it fixed); numeric ranges refer to the 5 to 95% credible intervals derived from Bayesian output.
- Spawning biomass (mature females only) at the beginning of 2011 is estimated to be in the range of 12-43% or 8-24% of the equilibrium unexploited value.
- Annual exploitation rates have increased since the 1980s, and are approaching or have reached the historic high levels associated with the large catches by foreign fleets in the late 1960s. The exploitation rate for 2010 is estimated to be in the range 0.041-0.152 or 0.089-0.224.
- Based on the DFO *Sustainable Fisheries Framework*, Precautionary Approach compliant limit and upper reference points of $0.4B_{MSY}$ and $0.8B_{MSY}$ were calculated (where B_{MSY} is the spawning biomass at the maximum sustainable yield). The spawning biomass at the start of 2011 has a probability of 0.96 or 0.82 of being above $0.4B_{MSY}$, and of 0.68 or 0.24 of being above $0.8B_{MSY}$.
- Constant catch projections at 3,500 t/year (which is the average catch from 2006 to 2010) over 5 years predict that the spawning biomass at the start of 2016 would have a probability of 0.91 or 0.57 of remaining above $0.4B_{MSY}$, and of 0.63 or 0.15 of remaining above $0.8B_{MSY}$.
- Both model runs estimate that since 1981 there have been no recruitment events as large as those observed in the early 1950s and late 1970s. There is evidence that an above average recruitment event occurred in the early 2000s, although there have been insufficient observations of this year class to be confident of its size.

INTRODUCTION

Pacific ocean perch (*Sebastes alutus*) is a long-lived, commercially important species of rockfish found along the rim of the North Pacific and is the most abundant rockfish species on Canada's west coast. The life history of Pacific ocean perch (POP) follows similar patterns to other *Sebastes* species, with a free swimming pelagic larval stage that can last from three to twelve months before settling to the bottom as juveniles. Juvenile benthic habitat is typically shallow (100-200 m), compared to the depths occupied by adult POP, and comprises either rough rocky bottoms or high relief features such as boulders, anemones, sponges, and corals.

Pacific ocean perch supports the largest rockfish fishery in British Columbia (BC) with an annual coastwide TAC (total allowable catch) of 6,148 t. The trawl fishery receives 99.98% of the coastwide TAC, with the rest allocated to the hook and line fishery.

The assessment is based on catches reported from Pacific Marine Fisheries Commission (PMFC) major areas 5A, 5B, and 5C (combined as 5ABC) as shown in Figure 2. These areas include the main Queen Charlotte Sound (QCS) POP population, bounded by the southern tip of Moresby Island, the northwest tip of Vancouver Island, and extending to the mainland and into

southern Hecate Strait. The definitions of the PMFC areas differ from the Groundfish Management Areas (GMAs) used by the DFO Groundfish Management Unit (Figure 2). Current TACs for POP are 2,070 t for combined GMAs 5AB and 2,118 t for combined GMAs 5CD.

Advice to managers is presented as decision tables that provide probabilities of exceeding reference points for each year of five-year projections across a range of constant catch scenarios. The reference points used are the provisional reference points described in DFO (2009). These are the "limit reference point" (below which the stock should never go) of $0.4B_{MSY}$ and an "upper stock reference point" of $0.8B_{MSY}$, where B_{MSY} is the spawning biomass associated with the maximum sustainable yield (MSY). The zone below the limit reference point is termed the "critical zone" while the zone lying between the two reference points is termed the "cautious zone". The region above the upper stock reference point is termed the "healthy zone". All reference points and the associated probabilities were derived from the posterior distributions of Bayesian computations.

ASSESSMENT

The assessment used an annual two-sex catch-at-age model tuned to three fishery-independent trawl survey series (Goose Island Gully historic, QCS synoptic and QCS shrimp), annual estimates of commercial catch since 1940, and age composition data from two of the survey series (8 years) and the commercial fishery (29 years). Growth parameters were estimated from POP length and age data using biological samples collected from 1978 to 2009.

The model assumed that the initial population was at an unfished equilibrium in 1940. The survey data covered the period 1967 to 2010 (although not all years were represented) and the age composition data began in 1978. The model was implemented in a Bayesian framework under four scenarios, in which natural mortality, *M*, and steepness of the stock-recruit function, *h*, were each either fixed or estimated. The Markov chain Monte Carlo (MCMC) procedure was used to determine the joint posterior distribution of the parameter estimates for each of the investigated scenarios. The two model runs that estimated *h* were endorsed as being equally plausible, while the two runs where *h* was fixed (based on arguments against fixing *h*) were rejected. The two accepted model runs are termed 'Estimate *M* & *h*' and 'Estimate *h*' respectively, with *M* being fixed in the second run.

The median estimate of natural mortality in the 'Estimate *M* & *h*' run is 0.067 (0.062-0.072) for females, and 0.073 (0.067-0.078) for males. These are higher than the fixed value of 0.06 used for female and male natural mortalities in the 'Estimate *h*' run, although the posterior distribution for both estimates are within the prior used to constrain the estimation process. The higher estimates for *M* in the 'Estimate *M* & *h*' run result in greater biomass levels, less depletion, and a more optimistic estimate of the current stock status than for the 'Estimate *h*' run.

Both accepted model runs fit the available data well. The posterior distributions of the vulnerable biomass (the biomass available to the fishery) for each year by model run are shown in Figure 3. Figure 4 shows the median estimate of the spawning biomass (mature females only) at the start of year t, B_t, and vulnerable biomass as fractions of the unfished equilibrium values. The biomass (whether spawning or vulnerable) is estimated to have increased in the early 1960s due to an episode of good recruitment, but then declined with the very large catches made by the foreign fleets. The biomass continued to decline until the mid-1980s, but then increased in spite of increasing catches, due to strong year classes that were spawned in the late 1970s. The biomass declined after about 1990, with an apparent halt near 2006.

The current spawning biomass is estimated to be 0.26 (0.12-0.43) or 0.14 (0.08-0.24) of unfished equilibrium levels. These are historic low levels (Figure 4). The estimated ratio of B_{MSY} to unfished equilibrium biomass is 0.25 (0.17-0.35) or 0.24 (0.16-0.32).

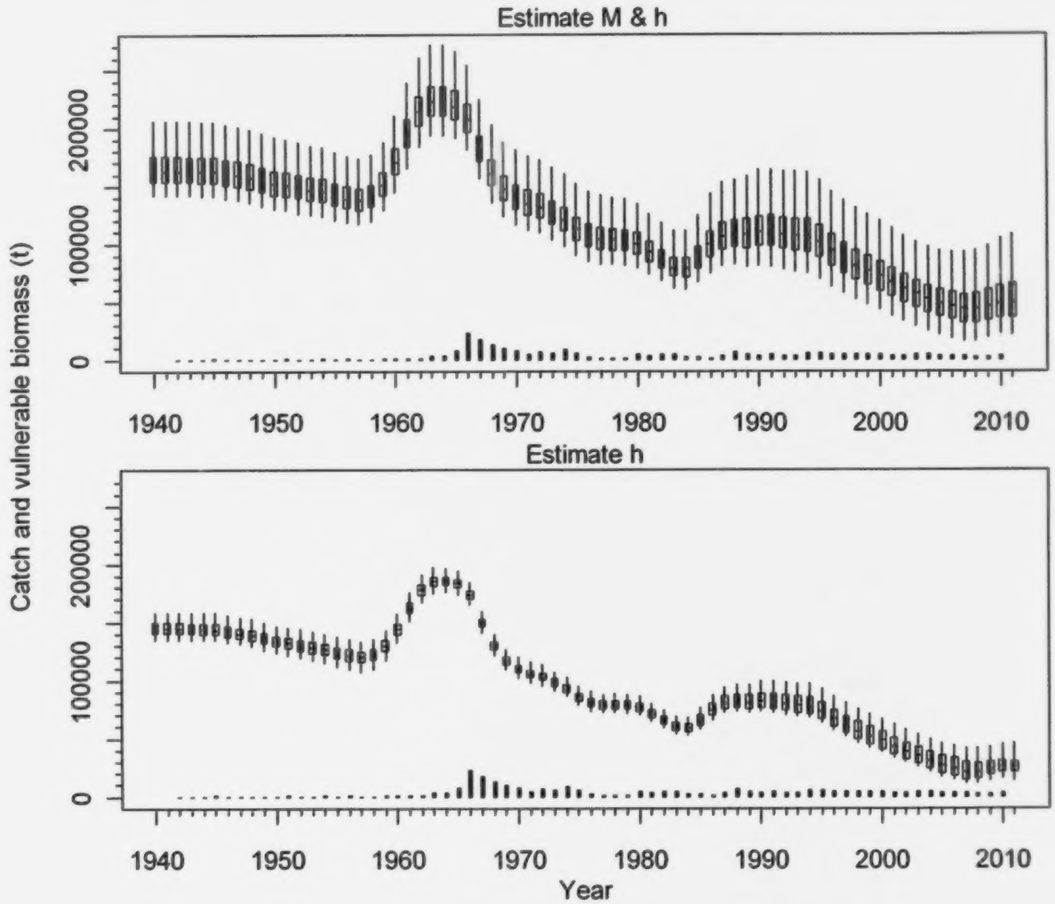

Figure 3. Annual commercial catch (vertical bars) and vulnerable biomass (boxplots showing 2.5, 25, 50, 75 and 97.5 percentiles of the posteriors from the Markov chain Monte Carlo, MCMC, results) for the two accepted model runs.

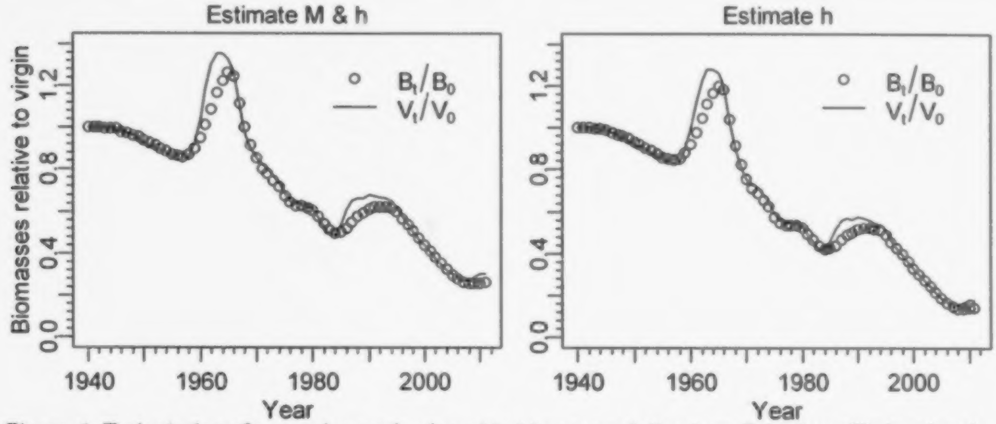

Figure 4. Trajectories of spawning and vulnerable biomass relative to unfished equilibrium levels, Bt / B0 and Vt / V0 respectively, shown as medians of MCMC posteriors for the two accepted model runs.

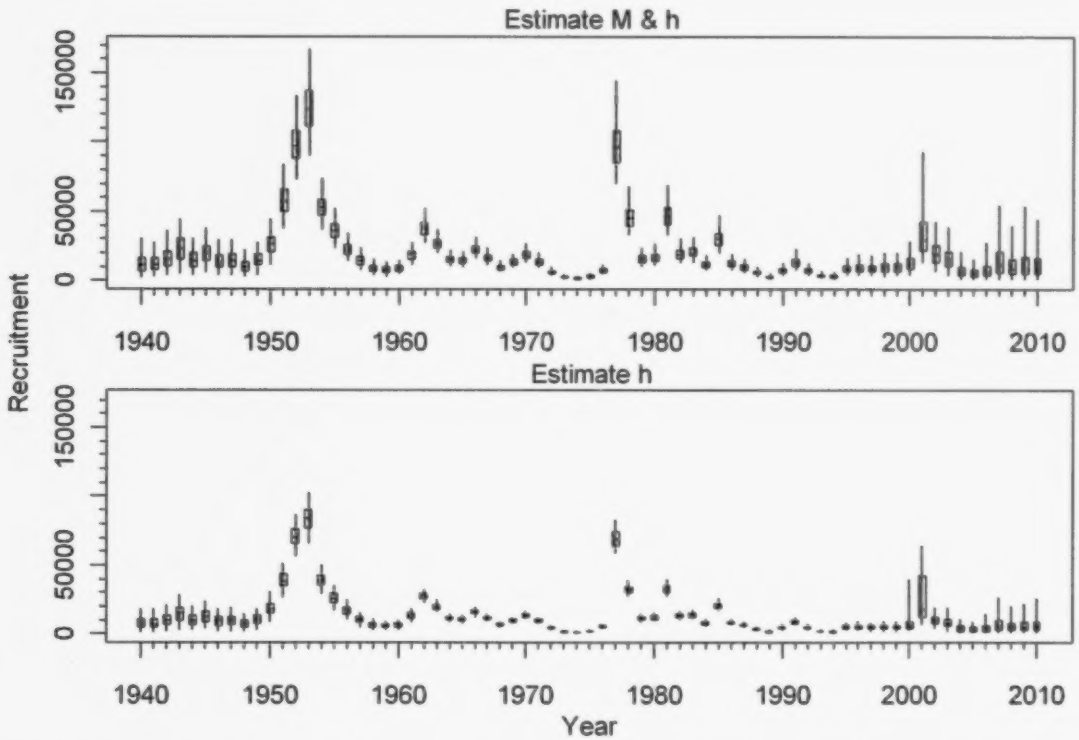

Figure 5. Annual marginal posterior distributions of recruitment in 1000's of age 1 fish for the two accepted model runs. Boxes give the 2.5, 25, 50, 75 and 97.5 percentiles from the MCMC results.

Figure 5 shows box plots of the posterior distributions of age 1 recruitment over time for each model run. The qualitative pattern is the same for both runs, estimating strong recruitment events in the early 1950s and late 1970s that resulted in subsequent biomass increases. However, recruitment after 1981 has been low, with 21 or 23 (depending on the model run) of

the 29 years having below average recruitment. There is evidence for an above average recruitment spike in 2001, but more observations of this year class are required before we can be confident of its relative size. Recruitment after 2001 is uncertain because these fish have not yet been fully selected to the commercial fishery and to the surveys.

Figure 6 indicates that annual exploitation rates were high during the period when catches by the foreign fleets in the late 1960s to mid-1970s were large. Exploitation declined from 1977 when Canada exercised its 200 nautical mile fisheries jurisdiction and excluded the foreign fleets, and then has steadily increased from the early 1980s with the development of a domestic fleet. Exploitation is estimated to be approaching or at historic high levels. Most of the posterior distribution of U_{2010}/U_{MSY} (the ratio of the current exploitation rate to the exploitation rate associated with MSY) lies below one for the 'Estimate *M* & *h*' run, with a median value near 0.8 (Figure 7), indicating that the current exploitation rate is most likely less than U_{MSY}. For the 'Estimate *h*' run, the median of U_{2010}/U_{MSY} is about 1.5, and most of the posterior distribution lies above one, indicating that the current exploitation rate is above that associated with MSY.

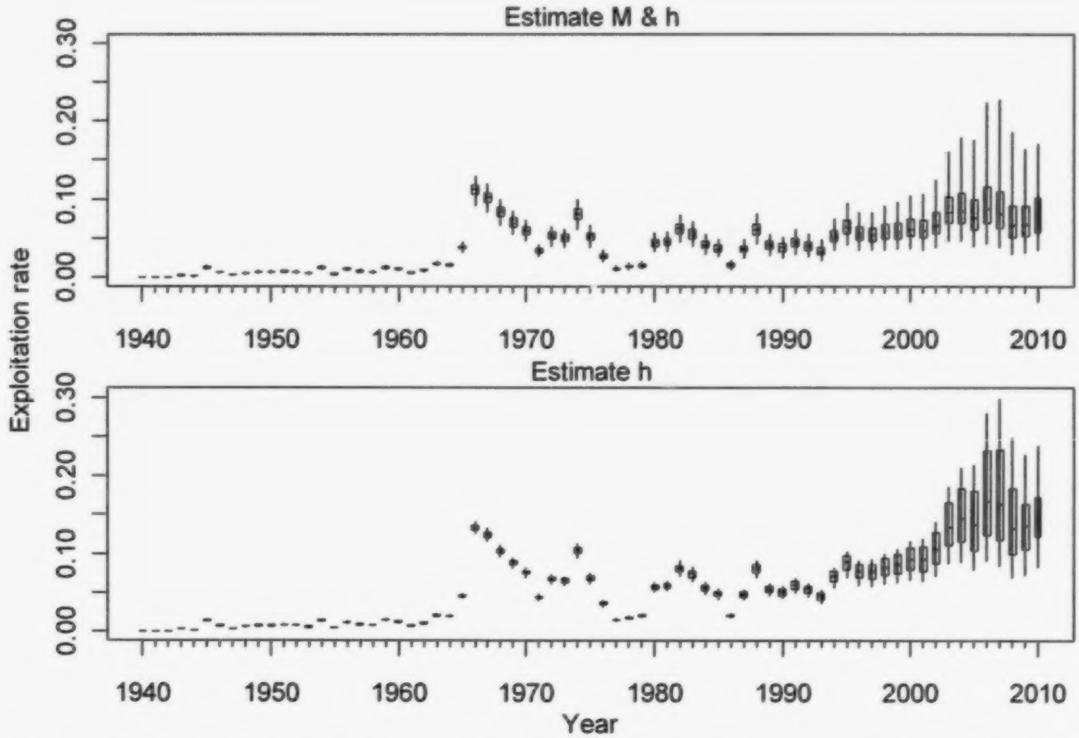

Figure 6. Annual marginal posterior densities of annual exploitation rate U_t (defined as the ratio of total catch in year t to the estimated vulnerable biomass in the middle of year t) for the two accepted model runs. The boxes give the 2.5, 25, 50, 75 and 97.5 percentiles from the MCMC results.

Figure 7 shows that the estimated spawning biomass at the beginning of 2011 almost certainly lies above the limit reference point for the 'Estimate *M* & *h*' run ($P(B_{2011} > 0.4B_{MSY}) = 0.96$), with the median lying in the healthy zone and the bulk of the distribution lying above the upper stock reference point ($P(B_{2011} > 0.8B_{MSY}) = 0.68$). For the 'Estimate *h*' run, the probability that the estimated spawning biomass at the beginning of 2011 exceeds the limit reference point is $P(B_{2011} > 0.4B_{MSY}) = 0.82$. The median estimated spawning biomass is below the upper stock reference point ($P(B_{2011} > 0.8B_{MSY}) = 0.24$), thus lying within the cautious zone with tails of the

distribution extending into both the critical zone and the healthy zone (i.e. the horizontal dashed blue line extends above and below the vertical grey lines).

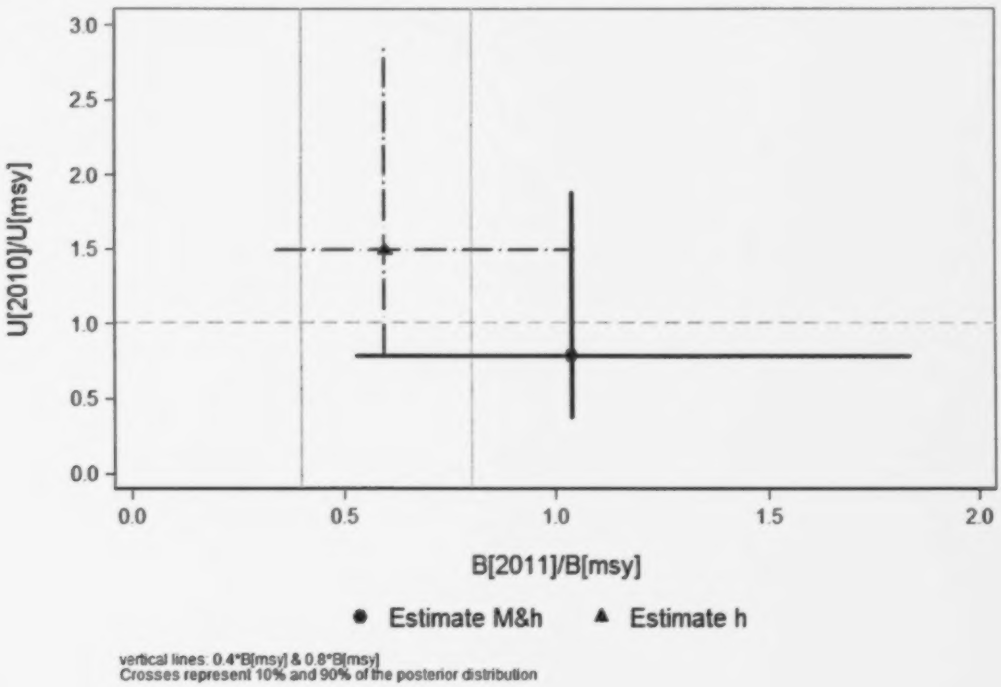

Figure 7. Cross plots showing the medians and the 10-90% credibility intervals for the ratio U_{2010} / U_{MSY} against the ratio B_{2011} / B_{MSY} for the two accepted model runs. Vertical lines at 0.4 and 0.8 correspond to the default limit and upper stock reference points of $0.4B_{MSY}$ and $0.8B_{MSY}$.

Projections were made for five years, applying a set of constant catches to the MCMC-generated posterior distributions of the parameters. Management advice is presented in the form of decision tables which give the probability of exceeding the "Precautionary Approach" compliant limit and upper stock reference points for catches from 0 to 6,000 t/year. Figures 8 and 9 show the probability of exceeding the two reference points ($0.4B_{MSY}$ and $0.8B_{MSY}$) in 2016 over the range of catches. Tables 1 and 2 give the probabilities for each year from 2011 to 2016 for a subset of the catches.

For projections using the current average (2006 to 2010) catch level of 3,500 t/year, the 'Estimate *M* & *h*' run estimates that the probability of the population being above the limit reference point at the start of 2016 is $P(B_{2016} > 0.4B_{MSY}) = 0.91$, and of being in the healthy zone at the start of 2016 is $P(B_{2016} > 0.8B_{MSY}) = 0.63$. For the 'Estimate *h*' run, the respective probabilities are $P(B_{2016} > 0.4B_{MSY}) = 0.57$ and $P(B_{2016} > 0.8B_{MSY}) = 0.15$.

These projections primarily use recruitments which were estimated in the period prior to the projections. This is because the simulated recruitments generated during the projections do not contribute to the fishery or the mature population because of the lag in the selectivity functions, a greater lag in the maturity ogive, and the short time frame of the projections.

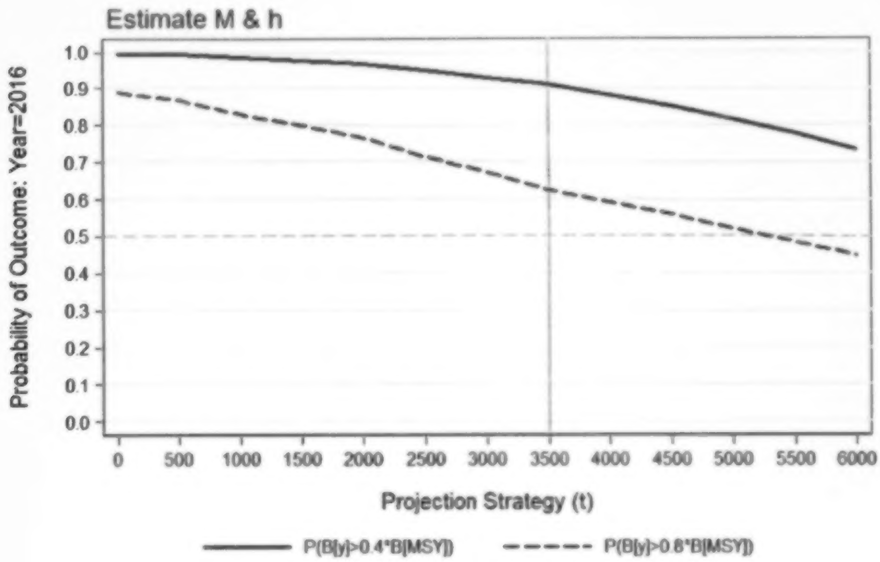

Figure 8. Probabilities of the spawning biomass at the start of 2016, B_{2016}, exceeding $0.4B_{MSY}$ and $0.8B_{MSY}$ over a range of constant catch scenarios for the 'Estimate M & h' run. The solid vertical line indicates the approximate average catch over the most recent 5 years.

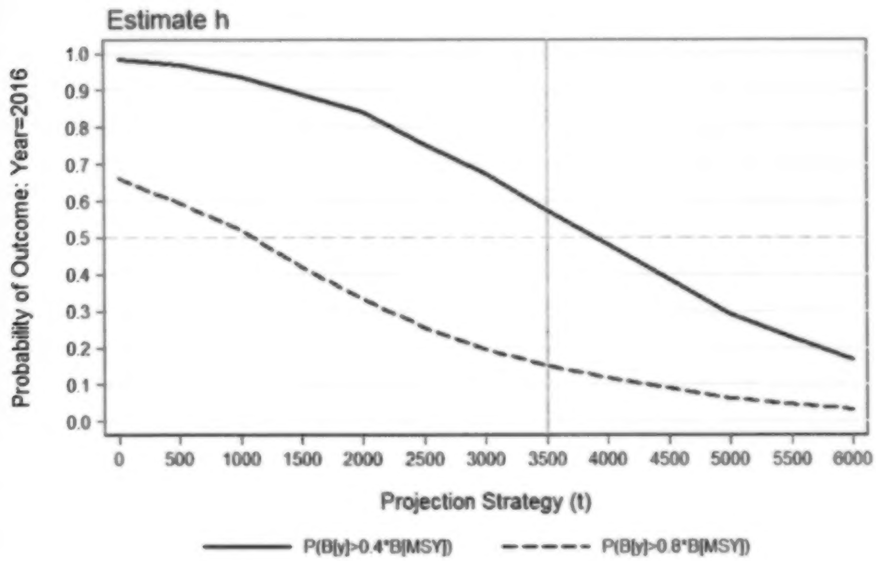

Figure 9. As for Figure 8 but for the 'Estimate h' run.

The accuracy of the projections in the decision tables depends on the validity of the model. Uncertainty in the parameters is explicitly addressed using a Bayesian approach but reflects

only the specified model and weights assigned to the various data components. Future updates depend on the continuation of data collection (from ongoing surveys, assimilation of catch data and sampling of commercial catches).

Table 1. Decision tables detailing the limit reference point $0.4B_{MSY}$ for 1-5 year projections for the two accepted model runs. Values are $P(B_t > 0.4\,B_{MSY})$, i.e. the probability of the spawning biomass at the start of year t being greater than the limit reference point. The probabilities are based on the MCMC posterior distributions of B_t and B_{MSY}. Catch strategies are in increments of 1000, plus the value of 3500 which is the approximate average catch over the last 5 years. The final column values trace out the solid black lines in Figures 8 and 9.

Annual catch strategy	Projection Year					
	2011	2012	2013	2014	2015	2016
	Run: Estimate *M* & *h*					
0	0.957	0.976	0.989	0.993	0.997	0.997
1000	0.957	0.971	0.981	0.985	0.988	0.986
2000	0.957	0.968	0.969	0.969	0.969	0.968
3000	0.957	0.964	0.961	0.956	0.937	0.931
3500	0.957	0.956	0.956	0.939	0.926	0.911
4000	0.957	0.953	0.943	0.924	0.909	0.884
	Run: Estimate *h*					
0	0.816	0.895	0.942	0.966	0.981	0.985
1000	0.816	0.873	0.905	0.922	0.932	0.935
2000	0.816	0.846	0.857	0.859	0.855	0.844
3000	0.816	0.818	0.801	0.766	0.723	0.674
3500	0.816	0.800	0.762	0.712	0.652	0.574
4000	0.816	0.783	0.728	0.659	0.564	0.484

Table 2. As for Table 1, but for the upper reference point $0.8\,B_{MSY}$, such that values shown are $P(B_t > 0.8\,B_{MSY})$ and the final column values trace out the dashed red lines in Figures 8 and 9.

Annual catch strategy	Projection Year					
	2011	2012	2013	2014	2015	2016
	Run: Estimate *M* & *h*					
0	0.680	0.754	0.810	0.847	0.875	0.890
1000	0.680	0.741	0.777	0.800	0.823	0.835
2000	0.680	0.720	0.738	0.762	0.764	0.759
3000	0.680	0.693	0.705	0.699	0.689	0.674
3500	0.680	0.685	0.679	0.671	0.650	0.626
4000	0.680	0.676	0.663	0.644	0.615	0.584
	Run: Estimate *h*					
0	0.239	0.317	0.437	0.546	0.613	0.661
1000	0.239	0.288	0.365	0.426	0.477	0.515
2000	0.239	0.260	0.292	0.324	0.334	0.333
3000	0.239	0.239	0.236	0.226	0.213	0.197
3500	0.239	0.225	0.209	0.189	0.168	0.152
4000	0.239	0.215	0.189	0.163	0.143	0.119

Sources of Uncertainty

Although QCS POP is the most data-rich rockfish stock in western Canadian waters, the amount of historical data available to support the interpretation of the long early catch history is small, particularly for the early stock reconstruction. There are no biomass indices prior to the mid-1960s and the available age composition data are all relatively recent (starting in 1978). It is fortunate that the earliest available age data are able to provide information on year class strengths in the 1950s and 1960s, due to the long-lived nature of the species and the apparent high precision of the ageing methodology. Furthermore, the observation that the declining trend has halted is largely based on the two active surveys that each show a levelling off in the estimated indices. But this is only a recent observation that may not continue, and the projections suggest a declining stock if current catches are maintained.

CONCLUSIONS

The two accepted model runs from the assessment depict a slow-growing, low productivity stock that was heavily exploited by foreign commercial fleets for a decade starting in the mid-1960s. It appears that this early fishery was sustained from a strong recruitment event that occurred in the early 1950s. The depletion of this stock halted briefly after the 1977 introduction of the 200 nautical mile limit, before resuming with the development of a domestic bottom trawl fleet. The domestic fishery was sustained from a few strong year classes spawned in the late 1970s and early 1980s. Current spawning biomass is estimated to be at historic low levels. Exploitation rates are estimated to be approaching or at historic high levels.

The two model runs provide substantially different advice with respect to current and projected stock status due to the different assumptions regarding natural mortality. The model run that estimated natural mortality is associated with higher productivity and a more optimistic stock size relative to B_{MSY} than the run that fixed mortality. Both model runs fit the available data well, and the review committee agreed that they were equally plausible. Therefore, results from both model runs are presented in the decision tables (Tables 1 and 2) for the provision of advice.

SOURCES OF INFORMATION

This Science Advisory Report has resulted from a Fisheries and Oceans Canada, Canadian Science Advisory Secretariat Pacific Regional Advisory Meeting of November 24, 2010 on Stock Assessment for Pacific Ocean Perch (*Sebastes alutus*) in Queen Charlotte Sound, British Columbia. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

DFO. 2009. A fishery decision-making framework incorporating the Precautionary Approach, (last modified 23 May 2009). http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/sff-cpd/precaution-eng.htm

FOR MORE INFORMATION

Contact: Dr. Andrew Edwards
Pacific Biological Station, Fisheries and Oceans Canada
3190 Hammond Bay Road, Nanaimo, British Columbia V9T 6N7
Tel: 250-756-7146
Fax: 250-756-7053
E-Mail: Andrew.Edwards@dfo-mpo.gc.ca

This report is available from the:

Centre for Science Advice (CSA)
Pacific Region
Fisheries and Oceans Canada
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

Telephone: 250-756-7208
Fax: 250-756-7209
E-Mail: CSAP@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs

ISSN 1919-5079 (Print)
ISSN 1919-5087 (Online)

La version française est disponible à l'adresse ci-dessus.

CORRECT CITATION FOR THIS PUBLICATION

DFO. 2011. Stock assessment for Pacific ocean perch (*Sebastes alutus*) in Queen Charlotte Sound, British Columbia in 2010. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/017.